Tanzania Journal of Science
Volume 51(4), 2025
journal homepage: https://commons.udsm.ac.tz/tjs/

Appropriate wireless technology for blue data communication to enhance artisanal fishery

Abdi T Abdalla[1], Eva Shayo[1*], Angelina Misso[1], Baraka Maiseli[1], Kwame Ibwe[1], Narriman Jiddawi[2], Moses Ismail[1]
[1]*Department of Electronics and Telecommunications Engineering, University of Dar es Salaam, Dar es Salaam, Tanzania*
[2]*Department of Marine and Coastal Resources Management, Institute of Marine Sciences, Zanzibar*
University of Dar es Salaam P. O. Box 35134, Dar es Salaam, Tanzania.

Keywords

Artisanal Fishery;
Data Communication;
LoRAWAN;
Smart Fishing;
Wireless Technology

Abstract

The paper examines the development of a system architecture to support smart fishing. This includes the establishment of a blue data center, which would allow government agencies and research institutions to access fisheries data. The goal is to provide policymakers with the tools they need to efficiently manage artisanal fisheries resources. The architecture also incorporates wireless communication components that are suitable for small-scale fishers in remote areas. The study delves into the selection of appropriate wireless communication technology for transmitting fishing data to the communication center. Factors such as coverage range, data rates, and cost implications are taken into consideration. The evaluation results indicate that long-range wide area network (LoRaWAN) technology is the most suitable choice for facilitating the artisanal fishing architecture. LoRaWAN offers satisfactory coverage distance, low power requirements, and an overall cost-effective solution. The research underscores the significance of leveraging technological solutions to advance the fisheries sector. It highlights the existing gap between current practices and technological advancements, emphasizing the need for progress in this field. This study contributes to applied communication science by addressing the real-world challenge of selecting optimal low-power wireless technologies for sustainable blue data transmission in artisanal fisheries.

Introduction

Smart fishing involves the use of high-tech digital systems to optimize and manage fish harvested from water resources (Mustafa 2016, Abdalla et al. 2022). The deployment of advanced technological solutions in the fisheries industry increases productivity and promotes proper fishing practices (Yang et al. 2021). This advantage ensures the sustainability of fish populations and guarantees increased revenue streams for fishermen. Additionally, smart fishing proves to be particularly useful for small-scale fishermen who employ traditional fishing methods (Andrew et al. 2007, Schuhbauer et al. 2019). Instead of making multiple physical visits to fishing sites, which can be dangerous, inconvenient, time-consuming, and costly, smart fishing enables remote monitoring and visualization of fish from the landing sites. As a result, fishermen can make informed decisions about fish quality and plan their visits to fishing sites for optimal harvesting. Given these advantages, researchers must establish efficient methodologies and architectures that support smart fishing.

Despite the potential benefits of smart fishing, fishermen from most developing countries continue to use traditional fishing methods (March and Pierre 2022, Abdalla et al. 2023). This practice has resulted in frequent reported misplacements and deaths of fishermen[1,2]. In Tanzania, there have been commendable efforts by the country to address these concerns for advancing the fishing industry. For example, Zanzibar has recently introduced the Blue Economy policy[3] that, among its several objectives, centers on socio-economic development through improvement of fisheries infrastructure and related activities. The blue economy is increasingly recognized as a critical frontier for sustainable development, especially in coastal nations where marine resources contribute significantly to livelihoods and food security. However, most small-scale fisheries remain underserved by modern digital technologies that could enhance productivity, traceability, and conservation.

Inspired by recent technological advances, we have been developing a system architecture for smart fishing over the past few years. In addition, a Blue Data Centre has been integrated into the architecture, providing government agencies and research institutions with access to fisheries data. This data repository could assist policymakers and administrators in developing strategic plans for the efficient control and management of fish and other related natural resources.

Compared to existing architectures (Benjelloun et al. 2022), our proposed architecture includes wireless communication components specifically designed for small-scale fishers in resource-constrained remote areas. The architecture incorporates a microcontroller that collects information from various wireless sensor nodes deployed on fishing units, such as fish trap *dema*, fish

*Corresponding Author Email: shayo.eva@udsm.ac.tz
Received 12 Nov 2024, Revised 29 August 2025, Accepted 23 Dec 2025, Published 7 January 2026
https://doi.org/10.65085/2507-7961.1130

ISSN 0856-1761, e-ISSN 2507-7961

finder, fish net, fishnet, or fishing vessel. The microcontroller then transmits the aggregated sensor information to the communication centre using wireless communication technology. However, it is still unclear which communication technology is most suitable for transmitting blue data, which includes relevant fishing data such as the locations and status of fishing gears, the status of fish finders, vessel locations, and their respective registration and licensing information, as well as the volume and types of fish harvested. Therefore, the objective of this study is to identify the most appropriate wireless communication technology for supporting blue data transmission in artisanal fisheries. Specifically, the research question is 'Which wireless technology offers the best trade-off between coverage, cost, power efficiency, and data throughput for small-scale, resource-constrained fishing environments? Thus, the study investigates appropriate wireless technologies focusing on applied low-power communication systems to support blue data transfer in small-scale fisheries. By aligning smart fishing architecture with real-world constraints in power, cost, and coverage, the study advances applied ICT solutions for resource sustainability.

Current Practices in the Fisheries Industry in Tanzania

Fishery resources play a crucial role in providing food and contributing to the local economy in the coastal areas of Tanzania. Along the Tanzania coastline and surrounding islands, a variety of fishing techniques are used, including traditional methods such as basket traps, fence traps, nets, and hook and line techniques (Jiddawi and Öhman 2002).

The species composition and sizes of fish vary depending on the type of gear, technique, and location. For instance, Rehren et al. (2022) reported a total of 92 species from 29 families in the dema trap fishery in Zanzibar. On the other hand, other fishing gears like nets have recorded even more species, as observed by Jiddawi and Öhman (2002), who documented over 60 families of fish from different fishing gears in Matemwe and Mkokotoni.

In Tanzania, the artisanal fishery is characterized by the use of simple, passive fishing gears. These gears are mostly used in depths that do not exceed 30 meters. There are at least 15 different types of fishing gears used, including: gillnets, cast net, seine nets, drag nets, scoop net, basket trap, fixed traps like weir and fence, handline, longline, troll lines, octopus spearing spear, stick, harpoons, mosquito net, machete, torch, and trawl net (Ali et al. 2023).

In general, different vessels are used to catch different types of fish, and most of them are not motorized. This limits the ability of fishermen to venture far into offshore waters. For instance, outrigger canoes primarily target nearshore species like snappers, emperors, rabbitfish, and groupers. On the other hand, dhows and larger boats are used to catch larger fish such as marlin, kingfish, sailfish, and tuna (Jiddawi and Öhman 2002). The various fishing vessels used include: canoe, outrigger canoe, dhow, boat, and dinghy.

Use of special equipment in small pelagic fishery

The use of special equipment, particularly fiber boats, has seen a recent increase in the small pelagic fishery. This has resulted in improved catching ability, safety at sea, and working conditions for fishermen, ultimately leading to increased catches. For instance, in 2022, 13,000 tonnes of anchovies were caught in Zanzibar (OCG 2022). This artisanal fishery primarily utilizes purse seine nets, seine nets, scoop nets, and ring nets operated by motorized dhows and larger boats. Each fishing unit typically consists of 15 to 25 crew members. Additionally, this fishery plays a crucial role in regional trade, with the majority of exported products (such as dried anchovies) being sent to the Democratic Republic of Congo (DRC) (Bodiguel and Breuil 2015). Fishing activities are conducted on moonless nights, with fishers using kerosene pressure lamps to attract schools of fish. However, nowadays, generators are also being used. Safety measures for pelagic fishers include empty fuel containers, skiffs capable of accommodating up to 7 people, and fishing net floats and buoys.

The fishery acts prohibit the illegal use of fishing gears such as undersized mesh gillnets, beach seines, spear guns, and blast fishing. However, Jiddawi and Öhman (2002) argue that the demand for fishery resources has been steadily rising due to population growth and tourism development. Consequently, fishing pressure and the adoption of destructive gear and techniques have increased. Despite being prohibited by law, these destructive methods persist due to insufficient surveillance, enforcement, and public awareness.

Use of GPS and a fish finder

In a study conducted by Mutia and Sailale (2021) to explore the use of satellite remote sensing in identifying and locating Potential Fishing Zones (PFZ) for the pelagic fishery in the marine waters of Tanzania, it was found to be useful. As a result, smartphones were provided to artisanal fishermen to implement this practice. SMS messages were sent to local fishermen to guide them on where to locate fish, and according to the fishermen, this greatly helped them. The data collected from this method helped identify the peak fishing season and target areas for fishermen. However, the high cost of smartphones poses a challenge to the continuity of this practice.

Trials have been conducted by the Deep-Sea Fishing Authority as presented by Simtowe et al. (2011), to assist local communities in certain locations in using GPS for locating fishing grounds and navigation. Fishermen were given GPS devices to record the areas where they had been fishing, which helped map potential fishing areas. This has improved the time taken to reach fishing grounds, increased precision in returning to previously fished areas, and consequently increased income. For example, the project trained and provided GPS devices to three fishing communities in Kigamboni. The main advantages of GPS include lower operating costs, precise navigation, and robustness in bad weather situations. Therefore, the use of GPS is crucial for reducing costs, increasing efficiency, improving fisheries management, and enhancing incomes. It is necessary to facilitate fishers' access to better fishing grounds through training and investment in Fish Aggregating Devices (FADs).

In terms of fishery support services, there are specialized areas for fish craft building and repair, as well as locally conducted fishing gear manufacturing sites. However, there are very limited fish support services such as fish finders. According to a report in The Guardian newspaper on December 7th, 2022, the Ministry of Blue Economy Zanzibar plans to purchase 500 fishing boats, each with a length of 7m and equipped with engines, fish finders, and GPS.

Methodology

This study followed a structured comparative analysis approach to identify the most suitable wireless communication technology for artisanal fisheries data transmission in coastal Tanzania. The evaluation framework was built on four key criteria: (i) coverage range, (ii) power efficiency, (iii) data rate, and (iv) implementation cost. Data were obtained from a combination of peer-reviewed literature, vendor specifications, and technical reports. Technologies analyzed included LoRaWAN, WiFi, GSM, Zigbee, WiMAX, Bluetooth, and satellite systems. Each technology was evaluated based on its performance in small-scale, low-resource coastal environments. We performed a benchmarking exercise by mapping technical characteristics (e.g., range, power consumption, bandwidth) against the specific constraints observed in Tanzanian artisanal fisheries (e.g., low vessel power supply, long-range needs, infrastructure gaps). No field deployments were conducted; rather, we conducted a structured comparison informed by real-world use cases and performance reports. To validate suitability, qualitative thresholds were defined based on operational requirements in the field (e.g., minimum 5 km range, battery-based operation, data rates suitable for sensor telemetry). Technologies that failed to meet minimum constraints in two or more categories were excluded from final recommendations. The data used in this study were derived from secondary sources, including peer-reviewed journal articles, technical datasheets, and vendor documentation published between 2018 and 2023. Specific parameter values (e.g., transmission range, data rate, power consumption) were extracted from sources listed in the references. Where multiple values were available, average or representative values were selected based on common usage in related deployments. No raw or field-collected datasets were used; instead, a structured desk review was conducted to ensure comparability across technologies under similar environmental assumptions.

Overview of Wireless Communication Technologies

Artisanal fisheries are crucial for coastal communities around the world, as they contribute to local economies, food security, and cultural heritage (Lancker et al. 2019). However, artisanal fishing faces several challenges, including limited access to resources, competition from industrial fishing, sustainability concerns, and economic viability. Efforts are being made to support and promote sustainable artisanal fishing practices, protect the rights of small-scale fishermen, and ensure the long-term viability of coastal communities that depend on artisanal fisheries (Rousseau et al. 2019; Martínez-Escauriaza et al. 2021).

Artisanal fishermen have the option to utilize various wireless communication technologies to improve their fishing operations, safety, and connectivity with the wider fishing community (Bedón et al. 2021). While the availability and adoption of specific technologies can vary depending on the region and infrastructure, common wireless communication technologies include mobile phones connected to public networks, two-way radio using radio frequencies (RF), satellite communication, radio beacons and emergency locators, internet access through web-based platforms, WiFi, and Bluetooth technology. The availability and usage of these wireless communication technologies can vary depending on factors such as infrastructure, affordability, literacy levels, and government regulations.

Mobile phones are widely accessible and commonly used by artisanal fishermen. They provide voice communication capabilities, allowing fishermen to stay in touch with each other, coordinate fishing activities, and communicate with their families or local fishery management authorities (Meyer et al. 2022). Mobile phones also provide access to SMS messaging, which can be useful for receiving weather updates, market information, or emergency alerts.

Artisanal fishery plays a vital role in many coastal communities worldwide, contributing to local economies, food security, and cultural heritage (Lancker et al. 2019). However, artisanal fishing faces various challenges, including limited access to resources, competition with industrial fishing, sustainability concerns, and economic viability. Efforts are being made to support and promote sustainable artisanal fishing practices, protect the rights of small-scale fishermen, and ensure the long-term viability of coastal communities dependent on artisanal fisheries (Rousseau et al. 2019, Martínez-Escauriaza *et al.* 2021).

Artisanal fishermen can utilize a range of wireless communication technologies to enhance their fishing operations, safety, and connectivity with the wider fishing community (Bedón et al. 2021). While the availability and adoption of specific technologies can vary depending on the region and infrastructure, the common wireless communication technologies include mobile phones through public networks, radio frequency (RF) two-way radio, satellite, radio beacons and emergency locators, internet through web-based platforms, WiFi and Bluetooth technology. The availability and usage of these wireless communication technologies can vary depending on factors such as infrastructure, affordability, literacy levels, and government regulations.

Mobile phones are widely accessible and commonly used by artisanal fishermen. They provide voice communication capabilities, allowing fishermen to stay in touch with each other, coordinate fishing activities, and communicate with their families or local fishery management authorities (Meyer et al. 2022). Mobile phones also enable access to SMS messaging, which can be useful for receiving weather updates, market information, or emergency alerts.

Radio frequency communication technologies, such as VHF (Very High Frequency) radios and handheld transceivers, play a crucial role in the fishing industry. VHF radios are commonly used by fishermen on ships to communicate with each other and shore-based stations. They operate within specific frequency ranges and may require licensing in certain regions. Handheld transceivers, on the other hand, allow direct communication between nearby fishermen, facilitating coordination and information sharing (Calvert 1998).

In remote areas or offshore fishing grounds with limited or no mobile network coverage, artisanal fishermen rely on satellite communication systems (Belhabib et al. 2020). These satellite systems enable voice calls, text messaging, and data transmission, empowering fishermen to communicate with others beyond the reach of terrestrial networks (McClellan and Read 2010).

To ensure safety at sea, artisanal fishermen often equip their vessels with emergency communication and safety devices, such as emergency position-indicating radio beacons (EPIRBs) or personal locator beacons (PLBs) (Torres-Irineo et al. 2014). These devices can transmit distress signals with precise location information to search and rescue authorities in case of emergencies (Sharma and Sethulakshmi 2019).

Moreover, in areas with internet connectivity, artisanal fishermen can take advantage of web-based platforms, forums, and social media groups to exchange information, share fishing insights, discuss market trends, and stay updated on weather conditions or fishing regulations (Mallqui et al. 2019, Kusyama et al. 2022). These platforms serve as valuable tools for knowledge sharing, networking, and collaboration within the fishing community.

WiFi technology can be used in fishing harbors, landing sites, and community centers to provide local wireless connectivity (Aisyah et al. 2022). Fishermen can use WiFi to access the internet, communicate, and access online resources like weather forecasts or fishing regulations (Pramana et al. 2021).

Bluetooth technology, in addition to WiFi, enables short-range wireless communication between devices in proximity (Syefriana and Yohandri 2020). Fishermen can use Bluetooth-enabled devices to share information, exchange data, or connect peripheral devices such as sensors, GPS devices, or navigation systems (Behivoke et al. 2021, Kim et al. 2021).

Mesh networks use multiple interconnected devices to create a local network. In areas with limited connectivity, fishermen can create mesh networks using devices like smartphones or portable routers (Hsu et al. 2019). This allows them to establish communication within the network without relying on external infrastructure.

In certain instances, artisanal fishermen may receive support or initiatives from governmental or non-governmental organizations to improve their access to communication technologies, especially about safety and disaster response (Soejima and Frangoudes 2019). Local fishermen's associations or cooperatives frequently establish their own communication networks to facilitate the sharing of information and coordination among members (Mizuta and Vlachopoulou 2017). These networks may incorporate dedicated radios, phone directories, or community notice boards, enabling fishermen to share updates, exchange tips, or seek assistance (Puley and Charles 2022).

Evaluation of the Wireless Technologies for Blue Data Communication

Wireless technologies in land environment

Communications at sea are currently limited to the use of high frequency/very high frequency (HF/VHF) and satellite. HF communications have been extensively used to enable buoy-to-shore data transmissions, but they are proprietary and narrowband (Campos et al. 2016). VHF radios have been deployed to facilitate ship-to-ship and ship-to-shore communications, but they are also narrowband and limited to voice applications (Jorge and Santos 2013). Satellite communications can be used to access the Internet at sea and are commonly used to transmit data collected underwater, but they are proprietary, unaffordable, and still limited in bandwidth (Lopes et al. 2014). Broadband, standard wireless communications are available using land-based cellular networks and Wi-Fi communications at 2.4 GHz and 5 GHz unlicensed frequency bands, but typically enable near-shore operations only.

Several research works have been conducted to explore maritime communications solutions using WiMAX technology. For example, buoy-to-ship point-to-point communications have been evaluated using the 5.8 GHz licensed band (Lopes et al. 2014). WiMAX can provide broadband wireless access to users on board ships near the seaport area or coast. Additionally, WiMAX can serve as an alternative to satellite links for multimedia communications among different units within a few kilometers.

Other research has been conducted on Wi-Fi-based, long-range maritime communications, specifically focusing on providing high bitrate and cost-effective Internet access for fisheries (Jorge and Santos 2013). The findings from this study demonstrated the feasibility of achieving broadband ship-to-shore IP-based data communications within a transmission range of approximately 10 km. However, the use of Wi-Fi relies on the availability of ships to establish a multi-hop network, and real-time ship-to-shore communications cannot be guaranteed. Additionally, wireless communications near the water surface are subject to significant propagation limitations and are influenced by ocean conditions. In a separate study by (Campos et al. 2016), an alternative approach involving the use of balloons to lift radio relays in the sea was introduced, enabling wireless communications that are not restricted by sea conditions. However, this method has thus far been limited to single-hop communications and has primarily been utilized in military environments.

In the study conducted by Campos et al. (2016), an innovative communications solution was developed to provide broadband, cost-effective Internet access to remote ocean areas for regular devices. This solution utilizes standard wireless access technologies such as Wi-Fi and GPRS/UMTS/LTE. By deploying communication nodes at high altitudes, line-of-sight coverage is maximized, creating an airborne communications network that extends wired and wireless Internet access from shore to remote ocean areas.

The use of low-cost and low-power wireless technologies, such as IEEE 802.11af, which operate in sub-GHz frequency bands, has been discussed in a study by Zawia et al. (2018). IEEE 802.11af allows for communication range of up to 10 km when antennas are installed at high altitudes. The BLUECOM+ solution leverages multi-hop relaying techniques to extend the range from the gateway node to the communication node on shore (Campos et al. 2016). This solution utilizes air-air links at 500 MHz and LTE air-surface links running at

800 MHz, enabling land-sea communications at a rate of 3 Mbit/s up to 150 km from shore. Table 1 provides a summary of the wireless technologies commonly deployed for data transmission in the blue economy.

Table 1: Comparison of different wireless technologies in the land environment

Solution	Technology	Coverage Range	Data Rates	Application
BLUECOM+ (Campos et al. 2016)	500MHz for air-air interface and LTE at 800MHz for air-surface interface	Land-sea communication up to 150 km from the shore	Real-time communications up to 3 Mbit/s	Provide internet access between land and sea
(López et al. 2010)	Zigbee IEEE 802.15.4, 2.4 GHz	<75 m	250 Kbps	Used in fish farm pH and temperature monitoring
(Lopes et al. 2014)	WiFi IEEE 802.11a; 802.11b/g/n 5.8 GHz 2.4 GHz	<100 m	11/54/300 Mbps	Point to point link between fishing ship and shore in maritime application
(Zawia et al. 2018)	Bluetooth IEEE 802.15.1, 2.4 GHz	Up to 100m	Up to 480Mbps	
(Lopes et al. 2014)	WiMAX IEEE 802.16, 2–11 GHz	<10 km	<75 Mbps	In marine communication
(Alselek et al. 2022)	GSM,850/900/1800/1900 MHz	Dependent on service provider	9.6 Kbps	
	GPRS, 850/900/1800/1900 MHz	Dependent on service provider	56–144 Kbps	
(Chen et al. 2022)	LoRaWAN, 433 and 915MHz	Up to 8km	300 bits/s to 50 Kbit/s	Used to monitor water quality in fish farm

The Long-Range Wide Area Network (LoRaWAN) is an emerging wireless technology that can cover distances of up to 20 km using the unlicensed Industrial Scientific Mechanical (ISM) band. In an implemented IoT-based system, LoRaWAN has been used as a data transmission technology to monitor the water quality of fish farms (Chen et al. 2022). LoRaWAN can achieve data transfer rates ranging from 300 bits/s to 50 kbps and operates on a 433 or 915 MHz signal bandwidth. The network supports adaptive data transfer rates to ensure signal reliability in changing conditions. In the farming environment, LoRaWAN reached a transmission distance of 4 km without line-of-sight (LoS) and up to 8 km with LoS (Chen et al. 2022). The advantage of LoRaWAN for users is the ability to develop distributed nodes and integrate them into a commercial network, or establish a private network using their own LoRa area network. The technology also minimizes battery usage, especially when implemented with the Time Division Multiple Access Control (TDMA) mechanism (Shayo et al. 2023).

Communication technologies in undersea environment

The communication and navigation in the undersea environment are challenging unlike the terrestrial environment where radio frequencies can support WiFi and cellular networks as well as positioning systems such as GPS (Kaushal and Kaddoum 2016). The problem for reliable underwater communication is due to the wide range of physical processes in underwater environments. The existing underwater technology architecture presented in Figure 1 uses acoustic waves for communication whose performance is limited by low bandwidth, high transmission losses, time-varying multipath propagation, high latency and Doppler spread (Murad 2022).

Communication and navigation in the undersea environment pose unique challenges compared to the terrestrial environment. Unlike on land, where radio frequencies can support various technologies like WiFi, cellular networks, and GPS, underwater communication faces significant obstacles. These obstacles stem from the diverse array of physical processes that occur in underwater environments. The current architecture for underwater technology relies on acoustic waves for communication. However, this approach is hindered by limitations including low bandwidth, high transmission losses, time-varying multipath propagation, high latency, and Doppler spread (Murad 2022).

Acoustic modems are mainly used for transmitting data in the undersea environment. However, the amount of data that can be transmitted is still smaller compared to what can be transmitted on land (Mohsan et al. 2022). Underwater acoustic communication currently supports data rates up to tens of kbps for long distances spanning kilometers, and up to hundreds of kbps for short distances (a few meters). The acoustic link is classified as very long, long, medium, short, or very short, depending on the transmission distance (Table 2).

Table 2: Classification of Acoustic Link

Parameters\Classification	Very long	Long	Medium	Short	Very short
Range (km)	1000	10-100	1-10	0.1-1	<0.1
Bandwidth(kHz)	<1	2-5	About 10	20-50	>100
Data rate (Approximately)	600bps	5kbps	10kbps	30	500kbps

Various underwater vehicles and sensors require a communication link with data rates ranging from a few to tens of Mbps. Large and stationary devices can use fiber optic or copper cables to achieve high data rates, but these options require significant engineering and maintenance. However, advancements in microprocessors have led to the development of on-board systems that process and analyze data on the platform. These systems transmit only the results rather than the entire observed data stream (Campagnaro et al. 2023).

Electromagnetic (EM) waves in the radio frequency (RF) range can be a good option for underwater wireless communication. They can achieve high data rate transfer in short distances at low frequencies, typically between 30 and 300 Hz (Ayaz and Uddin 2023). RF waves are also able to tolerate turbidity and turbulence in water. However, it is important to note that the attenuation of RF waves increases with frequency and they are heavily attenuated by seawater (Wan Hassan et al. 2022). Because of these factors, EM waves are not efficient for long-distance communication and lack channel control.

Table 3: Comparison of Undersea Communication Technologies

Parameters	Acoustic	RF	Optical
Attenuation	0.1 -4 dB/km	3.5-5 db/m	0.39 dB/m (ocean) 11dBm (turbid)
Speed (m/s)	1500 m/s	About 2.255exp8	About 2.255exp8
Data rate	Approx kbps	Approx Mbps	Approx Gbps
Latency	High	Moderate	Low
Distance	Up to kms	Up to about 10meters	About 10-100meters
Bandwidth	1-100 kHz, depending on distance	About MHz	10-150 MHz
Frequency band	10-15kHz	30-300 Hz	Exp 12 to exp 15
Transmission power	Tens of Watts	Few Mw to hundreds of Watts	Few Watts

On the other hand, optical waves have high bandwidth but are affected by other propagation effects such as temperature fluctuations, scattering, dispersion, and beam steering. Long fiber-optic cables can carry multiplexed data to the surface, offering real-time underwater communication and multimedia applications (Kaushal and Kaddoum 2016). Optical communication technology also offers smaller size and cost-effectiveness, as transceivers use laser diodes and photodiodes. This makes it possible for the next-generation Internet to deliver high bandwidth anywhere in the world. However, it is important to note that underwater communication using optical waves is limited to short distances due to severe water absorption at the optical frequency band and strong backscatter from suspended particles (Ayaz and Uddin 2023). Nevertheless, among the three major technologies differentiated in Table 3, optical communication technology stands out as the over-performing option for underwater communication. This is because there is a relatively low-attenuation optical window of blue-green wavelengths in the electromagnetic (EM) spectrum underwater.

Power constraints on wireless technologies

On the technology side, power availability continues to be a challenge. The longer a radio module needs to transmit, the more energy it will consume. The choice of wireless communication technology depends on factors such as the amount and frequency of data to be transmitted, transmission distance, and available energy. To address the power challenge, slow-moving or passive devices like floats and gliders can be used to sample the ocean for extended periods, although they can only cover a small area. Self-propelled systems require significant power to move through the ocean, and power consumption increases non-linearly with speed, leading to a drain on battery power. However, power-harvesting systems are being developed for ocean surface platforms like the Wave Glider or Saildrone (Yang et al. 2022). These platforms can harness wind and solar energy, allowing them to operate for months or even years. Bottom-mounted systems that utilize microbial fuel cells have also been deployed (Zhang et al. 2011). These fuel cells generate power by taking advantage of the natural oxidation of organic material in the sea. New battery technologies, such as aluminum-based systems that use seawater, show promise in significantly increasing battery capacity (Ali et al. 2023).

Conclusion

The primary objective of this study was to ascertain the optimal wireless communication technology for the efficient transmission of fisheries data. This investigation took into consideration various factors, including coverage range, power limitations, data rates, and implementation costs. Based on the findings, it is recommended that LoRaWAN technology be selected as the most suitable option, considering the aforementioned factors. Consequently, LoRaWAN will be incorporated into the smart fishing architecture to facilitate the transmission of pertinent data from the sensors to the communication center, thereby supporting artisanal fishery. This research underscores the significance of bridging the divide between technological solutions and ongoing initiatives that seek to advance Tanzania's fisheries sector. By establishing an intelligent fishing system architecture and integrating a blue data center, policymakers and administrators can have access to fisheries data, enabling them to devise strategic plans for effective resource management. The study thus contributes to the field of applied wireless technologies with practical implications for data-driven marine resource management.

Acknowledgment
This project is funded by the University of Dar es Salaam under project number CoICT-ETE23023.

References

Abdalla A, Haji N, Maiseli B, and Ibwe K 2022 IoT-Based Smart Fishing Gear for Sustainability of the Tanzania Blue Economy. *Tanzania J. Eng. Technol.* 41(3): 14–21.

Abdalla AT, Ibwe K, Maiseli B, Muhamed D, and Alawi M 2023 Towards ICT-Driven Tanzania Blue Economy: The Role of Higher Learning Institutions in Supporting the Agenda. *Lect. Notes Inst. Comput. Sci. Soc. Telecommun. Eng. LNICST* 499 LNICST487–497.

Aisyah AAW, Pujiharsono H, and Afandi MA 2022 Sistem Monitoring dan Kontrol Pakan Budidaya Ikan Lele menggunakan NodeMCU berbasis IoT. *J. Telecommun. Electron. Control Eng.* 4(2): 79-87.

Ali S, Bilame O, and Ngusa D 2023 An Assessment Of The Potentials Of Artisanal Fisheries In Spearheading The Blue Economy Transformation In Zanzibar Islands. *Glob. J. Agric. Sci.* 22(1): 23–35.

Andrew NL, Béné C, Hall SJ, Allison EH, Heck S, and Ratner BD 2007 Diagnosis and management of small-scale fisheries in developing countries. *Fish Fish.* 8(3): 227–240.

Ayaz M, and Uddin MA 2023 Performance Analysis of Underwater Wireless Optical Communication with Varying Salinity: Experimental Study. *Int. J. Intell. Syst. Appl. Eng.* 11(1): 18–24.

Bedón H, Lopez Pastor J, Cedeño Herrera E, and Nieto CM 2021 Marine Delay and Disruption Tolerant Networks (MaDTN): Application for Artisanal Fisheries, in *Communications in Computer and Information Science*,. pp. 3-17. Cham: Springer International Publishing, 2020.

Behivoke F, Etienne MP, Guitton J, Randriatsara RM, Ranaivoson E, and Léopold M 2021 Estimating fishing effort in small-scale fisheries using GPS tracking data and random forests. *Ecol. Indic.* 123: 107321.

Belhabib D, Cheung WWL, Kroodsma D, Lam VWY, Underwood PJ, and Virdin J 2020 Catching industrial fishing incursions into inshore waters of Africa from space. *Fish Fish.* 21(2): 379-392.

Benjelloun S, El Aissi MEM, Lakhrissi Y, and Ali SEH Ben 2022 Big Data Technology Architecture Proposal for Smart Agriculture for Moroccan Fish Farming. *WSEAS Trans. Inf. Sci. Appl.* 19: 311–322.

Bodiguel C, and Breuil C 2015 Report of the Meeting on the Small Marine Pelagic Fishery in the United Republic of Tanzania. Report/Rapport: SFFAO/2015/34. August/Août 2015. IOC-SmartFish Programme of the Indian Ocean Commission. FAO.

Calvert P 1998 *Training in Sea Safety Development Programmes*.

Campagnaro F, Steinmetz F, and Renner BC 2023 Survey on Low-Cost Underwater Sensor Networks: From Niche Applications to Everyday Use. *J. Mar. Sci. Eng.* 11(1): 125

Campos R, Oliveira T, Cruz N, Matos A, and Almeida JM 2016 BLUECOM+: Cost-effective broadband communications at remote ocean areas. *Ocean* 2016-Shanghai :pp. 1-6).

Chen C, Wu Y, Zhang J, and Chen Y 2022 IoT-Based Fish Farm Water Quality Monitoring System. *Sensors* 22(17): 6700.

Hsu WWY, Wang SY, Hong WS, Hu RH, Yu CJ, and Tasi HY 2019 Portable Fisheries Assistant Systems for Small Scale Fisheries Management, in *2019 IEEE Eurasia Conference on IOT, Communication and Engineering, ECICE 2019*.

Jiddawi NS, and Öhman MC 2002 Marine Fisheries in Tanzania. *AMBIO A J. Hum. Environ.* 31(7): 518–527.

Jorge L, and Santos S 2013 Wi-Fi Maritime Communications using TV White Spaces. Available online: https://paginas.fe.up.pt/~ee08251/tese/wp-content/uploads/2013/03/pdi_ee08251.pdf (accessed on 20 April 2025).

Kaushal H, and Kaddoum G 2016 Underwater Optical Wireless Communication. *IEEE Access* 41518–1547.

Kim S, Jeong J, Seo SG, Im S, Lee WY, and Jin SH 2021 Remote recognition of moving behaviors for captive harbor seals using a smart-patch system via bluetooth communication. *Micromachines* 12(3):Article 337

Kusyama SL, Machuve D, Kisangiri M, and Mfanga A 2022 Analysis of effectiveness of channels for information gathering and dissemination: Case of fisheries stakeholders in Mwanza and Mara regions of Tanzania. *African J. Sci. Technol. Innov. Dev.* 14(1): 183-193

Lancker K, Fricke L, and Schmidt JO 2019 Assessing the contribution of artisanal fisheries to food security: A bio-economic modeling approach. *Food Policy* 87(101740):1-14.

Lopes MJ, Teixeira F, Mamede JB, and Campos R 2014 Wi-Fi broadband maritime communications using 5.8 GHz band. *2014 Underw. Commun. Networking, UComms 2014* 5–9.

Mallqui JA, Martinez LP, and Aguirre JA 2019 Technological architecture based on internet of things to monitor the journeys of artisanal fishing, in *Advances in Intelligent Systems and Computing* 918: 598–608

March A, and Pierre F 2022 Small-scale fisheries development in Africa: lessons learned and. *Mar. Policy* 136(104925): 1–27.

Martínez-Escauriaza R, Gizzi F, Gouveia L, Gouveia N, and Hermida M 2021 Small-scale fisheries in madeira: Recreational vs artisanal fisheries. Sci. Mar. 85(4): 227–238

McClellan CM, and Read AJ 2010 Confronting the gauntlet: Understanding incidental capture of green turtles through fine-scale movement studies. *Endanger. Species Res.* 10(1): 227–236

Meyer S, Krumme U, Stepputtis D, and Zimmermann C 2022 Use of a smartphone application for self-reporting in small-scale fisheries: Lessons learned during a fishing closure in the western Baltic Sea. Ocean Coast. Manag. 224: Article 106186

Mizuta DD, and Vlachopoulou EI 2017 Satoumi concept illustrated by sustainable bottom-up initiatives of Japanese Fisheries Cooperative Associations. Mar. Policy 78: 143-149

Mohsan SAH, Mazinani A, Othman NQH, and Amjad H 2022 Towards the internet of underwater things: a comprehensive survey. Earth Sci. Informatics 15(2): 735–764.

Murad M 2022 *Escuela Técnica Superior de Ingeniería de Telecomunicación TESIS DOCTORAL Assessment and Performance Improvement of Multicarrier Modulation for Underwater Acoustic Communications Programa de Doctorado en Ingeniería de Telecomunicación*. PhD Thesis, University of Malaga.

Mustafa FH 2016 A Review of Smart Fish Farming Systems. J. Aquac. Eng. Fish. Res. 2(4): 193–200.

Mutia D, and Sailale I 2021 Application of Remote Sensing and GIS to Identifying Marine Fisheries off the Coasts of Kenya and Tanzania. Oceanography 34(4): 46–47.

OCGS 2022 Zanzibar Statistical Abstract 2021. Office of the Chief Government Statistician (OCGS), Revolutionary Government of Zanzibar: 1–150.

Pramana R, Suprapto BY, and Nawawi Z 2021 Remote Water Quality Monitoring with Early -Warning System for Marine Aquaculture, in E3S Web of Conferences,324: Article 05007

Puley M, and Charles A 2022 Dissecting co-management: Fisher participation across management components and implications for governance. Fish Fish. 23(3): 708–736

Rehren J, Samoilys M, Reuter H, Jiddawi N, and Wolff M 2022 Integrating Resource Perception, Ecological Surveys, and Fisheries Statistics: A Review of the Fisheries in Zanzibar. Rev. Fish. Sci. Aquac. 30(1): 1–18.

Rousseau Y, Watson RA, Blanchard JL, and Fulton EA 2019 Defining global artisanal fisheries. Mar. Policy 108: Article 103634.

Schuhbauer A, Cisneros-Montemayor AM, and Sumaila UR 2019 Economic Viability of Small-Scale Fisheries: A Transdisciplinary Evaluation Approach, in Chuenpagdee, R., Jentoft, S. (eds) Transdisciplinarity for Small-Scale Fisheries Governance, Cham: International Publishing, 2018. 93-117.

Sharma A, and Sethulakshmi CS 2019 Assessment of Occupational Hazards and Usage of Sea Safety Devices by Fishers of Kerala, India. J. Agromedicine 24(4): 461–470

Shayo, E. I., Abdalla, A. T., & Mwambela, A. J. (2023). Dynamic multi-frame multi-spreading factor scheduling algorithm for LoRaWAN. Journal of Electrical Systems and Information Technology, 10(1):1–21.

Simtowe F, Kassie M, Diagne A, Asfaw S, Shiferaw B, Silim S, and Muange E 2011 Determinants of agricultural technology adoption: The case of improved pigeonpea varieties in tanzania. *Q. J. Int. Agric.* 50(4): 325–345.

Soejima K, and Frangoudes K 2019 Fisheries women groups in Japan: a shift from well-being to entrepreneurship. *Marit. Stud.* 18(3): 297-304

Syefriana C, and Yohandri 2020 Pembuatan Alat Ukur Kedalaman Air Menggunakan depth meters. *Pillar Phys.* 13(1):49-56

Torres-Irineo E, Gaertner D, Chassot E, and Dreyfus-León M 2014 Changes in fishing power and fishing strategies driven by new technologies: The case of tropical tuna purse seiners in the eastern Atlantic Ocean. *Fish. Res.* 155:10-19.

Wan Hassan WH, Sabril MS, Jasman F, and Idrus SM 2022 Experimental Study of Light Wave Propagation for Underwater Optical Wireless Communication (UOWC). *J. Commun.* 17(1): 23–29.

Yang L, Huang J, Feng B, Zhang F, Zhang Y, Li X, Jian J, Wang Z, and Tong X 2022 Undersea Wireless Power and Data Transfer System With Shared Channel Powered by Marine Renewable Energy System. *IEEE J. Emerg. Sel. Top. Circuits Syst.* 12(1): 242–250.

Yang X, Zhang S, Liu J, Gao Q, Dong S, and Zhou C 2021 Deep learning for smart fish farming: applications, opportunities and challenges. *Rev. Aquac.* 13(1): 66–90.

Zawia HI, Hassan R, and Dahnil DP 2018 A Survey of Medium Access Mechanisms for Providing Robust Audio Video Streaming in IEEE 802.11aa Standard. *IEEE Access* 6: 27690–27705.

Zhang F, Tian L, and He Z 2011 Powering a wireless temperature sensor using sediment microbial fuel cells with vertical arrangement of electrodes. *J. Power Sources* 196(22): 9568–9573.